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TITLE

PROGRESS REPORT - SPRAYING WITH PENETRATING OILS TO CONTROL THE MOUNTAIN PINE BEETLE IN LODGEPOLE PINE

by
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Forest Insect Laboratory
Coeur d'Alene, Idaho
March 24, 1939

SUBJECT—

INDEX NO.—

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Mr. Keen

Refer to file
Studies C-1

Forest Insect Laboratory
Coeur d'Alene, Idaho
March 29, 1939

Dr. F. C. Craighead

Washington, D. C.

Dear Dr. Craighead:

I am enclosing a detailed report by Mr. Gibson, "Spraying with Penetrating Oils to Control the Mountain Pine Beetle in Lodgepole Pine", describing the results obtained from last season's experimentation on the Grand Teton National Park. It would seem that there can be no question as to the feasibility of this proposed method of control, for a number of the formulae tested during the past two seasons have given very satisfactory control.

As our tests were all made at the base of the tree, they have been obliged to overcome the factors of thick bark, excess moisture, and spots of uninfested cambium. As a result it would seem that more effective results should follow the treatment of the upper bole, provided a proper coverage can be obtained.

The formulae giving the most consistent results were those in the so-called "A" group:

	Results
Formula A	
Light stove oil, 3 parts	
Heavy stove oil, 1 part	Practically
Orthodichlorobenzene, 1 part (by volume)	98.5%
Naphthalene flakes, 3/4 lb. per gallon of oil	
Formula A-1	
Heavy oil (Diesel), 4 parts	
Orthodichlorobenzene, 1 part (by volume)	98.5%
Naphthalene flakes, 3/4 lb. per gallon of oil	
Formula A-2	
Light stove oil, 3 parts	
Heavy stove oil, 1 part	
Orthodichlorobenzene, 1/2 part (by volume)	
Naphthalene flakes, 3/8 lb. per gallon of oil	95.5%

Formula A-3
Light stove oil, 3 parts
Heavy stove oil, 1 part
Orthodichlorobenzene, 1 part (by volume) 97.5%
Naphthalene, 3.6 lb. per gallon of ortho-
dichlorobenzene (saturated solution)

In using naphthalene flakes heat is required to place this substance in solution with oil. Mr. Gibson shows that at 65° F. orthodichlorobenzene will dissolve and carry 3.6 lb. of naphthalene, which is .6 lb. more than used in Formula A. In Formula A-2 the orthodichlorobenzene and naphthalene are reduced by 1/2, with a listed result of 95.5 percent. Mr. Gibson states that he believes that if the examination of these trees had been made a few days later the results would have been comparable to A or A-1. It would therefore seem that our best approach to the problem of obtaining an effective and economical solution is to test the possibilities of the following two substances:

Heavy oil and a saturated solution of
orthodichlorobenzene and naphthalene flakes

The "B" group formulae can be discontinued for the present on the grounds of results obtained and the fact that heat is required to place naphthalene flakes in solution with oil.

Formula C, which uses orthodichlorobenzene and oil, gave fairly satisfactory results, although not as consistently good as the "A" group. It would seem that the addition of naphthalene flakes to the orthodichlorobenzene provides a more effective lethal agent. Ortho-dichlorobenzene is expensive, so an effort should be made to reduce the amount of this chemical that is required by adding to it some cheaper substance.

Formula M-1, or Diesel oil (2 parts) and ethylene dichloride (1 part) gave fairly satisfactory results, although the cost of 30 cents per gallon for the spray solution would make the cost rather prohibitive.

During the coming season we plan on using a wetting agent to break the surface tension of the oil, so as to increase penetration. If this can be done, as claimed by a number of commercial firms, it may be possible to reduce to a marked degree the amount of the more expensive lethal substance now required in the "A" group of formulae.

An outstanding development of last season's work is the duration of the effects of the successful treatments. During the low

daily temperatures of June, very little mortality followed the application of the spray. However, it seemed that there was sufficient penetration to arrest development, with mortality occurring several weeks later. Many of the insects recorded as living undoubtedly failed to develop to adult forms, so the listed mortality was even greater than shown. The fact that trees can be sprayed as late as July 7 is also of marked value in planning for the institution of control projects using this method of control.

As stated, your comments and suggestions will be greatly appreciated. We are working on plans for the coming season based upon the attempt to perfect one formula which can then be recommended for use. As stated, we would like to concentrate our efforts upon the use of Diesel oil, a wetting agent, and orthodichlorobenzene with naphthalene flakes in solution.

Respectfully yours,

JAMES C. EVENDEN
Senior Entomologist

Enclosures (2)

cc to:
Mr. Miller
Mr. Keen
Dr. Beal
Mr. Brown, New Haven, Conn.

PROGRESS REPORT - SPRAYING WITH PENETRATING OILS TO CONTROL THE MOUNTAIN PINE BEETLE IN LODGEPOLE PINE

by
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Coeur d'Alene, Idaho
March 24, 1939

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PROGRESS REPORT - SPRAYING WITH PENETRATING OILS TO CONTROL THE MOUNTAIN PINE BEETLE IN LODGEPOLE PINE

Introduction

In the search for cheaper and more effective methods of control to replace the method now used to combat the mountain pine beetle in lodgepole pine, personnel of the Coeur d'Alene Forest Insect Laboratory decided to experiment with the more promising penetrating sprays which members of the California Station had tested against the western pine beetle in ponderosa pine. It was felt a much better chance of successful control could be expected with those sprays on lodgepole pine, due to its thinner bark, than had been secured in the thicker-barked ponderosa pine. If successful, the method would obviate starting control on an area early in the spring when snow, muddy roads and inclement weather make working conditions extremely difficult and expensive. With the present methods, which involve the use of fire, an early season start is necessary because about the time good working conditions set in the project must be terminated due to the increasing fire hazard. Penetrating sprays do not require fire; control projects could be deferred until favorable working conditions became general, and continued until a few days prior to normal emergence of the mountain pine beetle. Obviously, better working conditions would be reflected in more and better work.

The sprays discussed consisted of a mixture of light and heavy stove oils to which had been added a material considered lethal to all developmental stages of bark beetles. The oils, in addition to carrying

the lethal material through the bark are more or less toxic themselves.

Work Prior to 1937

A preliminary experiment, made on mountain pine beetle infested lodgepole pine on the Beaverhead Forest in 1934, gave sufficiently encouraging results to justify further experimentation. Early in the summer of 1935 tests were continued near Antelope Flat on the Targhee Forest, where heavy losses from the mountain pine beetle were occurring in the lodgepole pine stands. Thirty-three infested trees sprayed with three different oils gave fairly good control and an opportunity to compare their effectiveness.

In October of the same year, a few trees were sprayed to test the possibilities of fall control. Examination of them the following spring revealed encouraging results.

From the control obtained in 1935 and 1936, it was apparent that oils containing orthodichlorobenzene and naphthalene caused the highest but not 100 percent mortality. Survivors were usually at the base of the tree where the bark was thick or green, but occasional survivors, for which no reason was apparent, were also present in other parts of the sprayed area.

The oils which had given the best results in 1935 and 1936 were given further tests in 1937. In addition, other formulae offering promise of giving good control were tried.

Trees selected for treatment covered as representative a set of site conditions as the locality afforded and contained brood to at least six feet.

Only one-half of the bark surface to a height of approximately five feet on the infested tree was treated, the untreated side serving as a source of normal activity data to be compared with control data from the treated side. Until 1938, usually the north side of the tree was selected for treatment in the belief that the small amount of sunlight reaching that portion would represent the most difficult test of the treatment. Sunlight is thought to increase the effectiveness of penetrating sprays having an oil base by raising the temperature of the bark and thereby facilitating absorption of the spray. Only a sufficient number of infested trees were sprayed on the south side to observe any unexpected effects that spraying on the north side might reveal. In addition, the selection of the base for treatment, where the bark is thicker, wetter and greener than on any other part of the tree, imposes the most difficult conditions to which the sprays could be subjected and yields data that furnishes a conservative estimate of the effectiveness of the treatment.

The boundaries of the treated portion of the tree were marked with lath fastened to the bark with shingle nails. Location of trees was by means of maps and numbered aluminum tags.

Spray was applied until the bark crevices and surface glistened from the liquid and drops began to form on the lower edge of the bark flakes, thus insuring thorough coverage.

It was learned from analysis of examination data that seven formulae had given excellent results. Four of these, however, seem too

costly to be practical for general control. The other three comprised a mixture of two kinds of penetrating oil and orthodichlorobenzene, or naphthalene or both. They gave such nearly complete control as to leave little to choose between them as far as effectiveness is concerned. Based upon cost of materials, the formula comprising only naphthalene in mixture with the two oils is the cheapest, but the necessity of heating the oil to dissolve the naphthalene probably places the ultimate cost of that formula on a par with the one containing the more expensive orthodichlorobenzene or even the one containing both naphthalene and orthodichlorobenzene.

Examinations made in 1937 revealed only a light brood to have been present in the treated trees. For that reason the survival of only one or two insects in a sampled treated area often greatly influenced the data. This condition, together with the necessarily limited sampling, where so many trees must be examined, caused wide variation in individual tree data and made definite conclusions of doubtful value.

Experiments Conducted in 1938

An extensive examination in early June of 1938 of the area where experiments had been conducted on the Targhee Forest revealed too light an infestation to supply sufficient trees for further tests. The new site selected for the tests was in Grand Teton Park on what is known as the Windy Point area, where a fairly heavy concentration of mountain pine beetle work has built up in the preceding few years.

Selection of Samples and Method of Treatment

In order to compare the effectiveness of formulae under the differing conditions of the two areas, it was decided to duplicate the promising 1937 tests at Grand Teton Park. Accordingly formulae A, B, and C, as well as other formulae, were tested.

Sampling the trees consisted of removing two one-quarter square foot samples near the center of the treated portion and about 2½ feet from the ground. Dead and living brood by developmental stages, bark condition and thickness, and other pertinent data were counted and recorded separately for each of these intensively examined one-quarter square foot samples. In addition, other parts of the treated area were intensively examined in order to be sure that the intensive samples were representative. Practically the same data was secured from both examinations except that dead insects were not recorded by developmental stages from the extensive sampling. Additional extensive examinations were made late in July of the trees where earlier sampling had not yielded conclusive data. Experimental procedure of 1937 was duplicated in 1938 except that the side of the tree selected for spraying was usually the most heavily infested. As that side varied as to direction such a selection gave an adequate test of all exposures.

A condition created by most of the treatments was the arresting of development of larvae over a more or less lengthy period before causing death. Usually larvae found in this condition were in the prepupal stage and could be detected by abnormal plumpness and lack of movement. Repeated proddings with a blunt pencil were often necessary

to produce the slight movement indicative of life in these insects. Arresting of development did not seem to be confined to larvae because practically no emergence of survivors was noted on treated areas, whereas untreated areas showed as much as 20 percent emergence.

The presence of more sickly larvae under bark treated with sprays containing only one lethal material indicated that these formulae were usually less rapid in lethal effect than those containing two lethal materials.

Other factors influencing brood survival under treated areas were thick, wet, and green bark. With some formulae these effects seemed quite definite, in others they could not be detected but in no case did they make a difference of more than a few percent of the total brood and for that reason have been omitted in discussing the results secured from each treatment.

Analysis of the data for the various treatments indicates that one of the major factors influencing survival is individual resistance of the insects to the effect of the treatment. This conclusion is based on field notes commenting upon the fact that insects had survived with no apparent reason for having done so.

It is recognized that some mortality would have occurred regardless of whether the trees were treated or not. However, this normal mortality, which cannot be credited to the effect of the treatment, generally has made so little difference in the total control secured, that it has been ignored.

The light stove oil referred to in this report is a fuel oil used in heating units. It has a Baume gravity of from 32 to 36. The heavy stove oil, also a fuel oil, has a Baume gravity of 28 to 32. The diesel fuel, used chiefly for tractors, has a 27+ Baume gravity.

Formulae tested

Formula A

This formula consisted of the following materials:

Light stove oil, 3 parts
Heavy stove oil, 1 part
Orthodichlorobenzene, 1 part (by volume)
Naphthalene, 3/4 lb. per gallon of oil

Twenty-five trees were treated with this formula on June 16 and an additional five on July 6, the latter to test the effectiveness of late spraying. The data from these treatments are shown in condensed form in table 1.

Of the 25 trees treated on June 16, the average mortality as determined from intensive examinations on July 11, 12, 13, and 25 was 96.2 percent, 12 of the trees showing complete control, 20 indicating 90 percent or better, and all having mortality greater than 80 percent. Data from the extensive examinations made on the same date indicated even more favorable results, 24 of the trees having mortality of 97 percent or better, and all showing 90 percent or better control. For both examinations the average control secured was about 97 percent. Five of the above trees, examined on July 25, showed less than one percent survival, and a second late season examination of some of those initially examined

TABLE I

MOUNTAIN PINE BEETLE INFESTED LODGEPOLE PINE TREATED WITH PENETRATING SPRAYS - TREATED JUNE 16 AND JULY 6, 1938

Formula A

Brood Per Square Foot

Date examined	Number of trees	On treated areas intensively examined: Dead Lar.	Dead Pup.	Dead N.A.	Living Lar.	Living Pup.	Living N.A.	On treated areas extensively examined: Dead Brood	Living Lar.	Living Pup.	Living N.A.	On untreated opposite side: Dead Lar.	Dead Pup.	Dead N.A.	Living Lar.	Living Pup.	Living N.A.
7/11, 12, 13	20[1]	93.0	7.3	.1	1.8	1.3	.9	76.9	1.2	.3	.3	1.8	.5	--	19.0	16.3	50.2
Totals		100.4			4.0			76.9	1.8			2.3			85.5		
7/25	5[1]	70.0	1.6	.4	.4	--	--	56.3	--	.3	--	.8	.8	--	24.0	--	50.4
Totals		72.0			--			56.3	.3			1.6			74.4		
7/27, 28	5[2]	15.2	71.2	48.8	--	--	--	77.6	--	--	.2	--	--	--	--	1.6	24.0
Totals		135.2			--			77.6	.2			--			25.6		

Percent of Dead and Living

(3) 7/11, 12, 13	20	92.6	7.3	.1	45.0	32.5	22.5	--	69.0	13.8	17.2	77.8	22.2	--	21.8	18.6	59.6
(4) Totals		96.2			3.8			97.7	2.3			2.6			97.4		
(3) 7/25	5	97.2	2.2	.6	100	--	--	--	--	100	--	50.0	50.0	--	30.9	--	69.1
(4) Totals		99.4			.6			99.4	.6			2.1			97.9		
(3) 7/27, 28	5	11.2	52.8	36.0	--	--	--	--	--	--	100	--	--	--	--	6.3	93.7
(4) Totals		100						99.7	.3			--			100		

(1) Treated June 16, (2) treated July 6, (3) by developmental stages for dead and living, (4) for area examined.

In the 20 trees examined July 11, 12 and 13 survival was apparently due to green areas on two trees, to wet bark on four trees, and to delayed effect of treatment in six trees, accounting for about 50 percent of the survival. No reason for the remaining survival is evident.

Wet bark was possibly responsible for the only survival in one of the five trees examined July 25.

Of the five trees sprayed on July 7, only one showed any survival when examined on July 28. No reason for this survival was evident.

on July 11 and 12 showed further mortality of the few survivors had occurred. From the data secured it seems reasonably safe to state that control of at least 98 percent of the brood was secured.

Late Spraying With Formula A

In order to secure some indication of the length of the period during which trees can be successfully treated with penetrating oils five trees were sprayed on July 6, which was not more than two weeks prior to the time emergence could be expected to start. The almost complete mortality on sprayed areas indicates treatment at that time is well within the period when control can be expected. The combined data from intensive and extensive examinations for these trees show 1,029 dead and one living insect, or less than .1 of one percent survival. A resume of the data is given in table 1.

Results of Treatment

This formula gave excellent results and is possibly the most dependable of the formulae tested, due in all probability to an excess of lethal materials which gives the formula what may be considered as a large safety factor. Its cost, though, is quite high, being about 34-1/2 cents per gallon.

Formula A-1

Composition of this formula was as follows:

Heavy oil (Diesel), 4 parts
Orthodichlorobenzene, 1 part (by volume)
Naphthalene, 3/4 lb. per gallon of oil

This formula varied from the previous one only in the oil used. This change in the "carrier", however, does not seem to have lessened the effectiveness of the formula.

A summation of the data reveals an average mortality of 97.7 percent in spite of the fact that only five of the 32 examinations of the 15 trees treated were made sufficiently late in the season to indicate completion of the lethal effects of the oils. Table II is a brief summation of the data secured.

As the carrier oil in this formula is the cheap Diesel fuel and it has given results equal to formula A, in which the more expensive mixture of light and heavy stove oils are involved, we may consider formula A-1, at 32 cents per gallon, to be slightly superior to formula A.

Formula A-2

Composition of this formula is as follows:

Light stove oil, 3 parts
Heavy stove oil, 1 part
Orthodichlorobenzene, 1/2 part (by volume)
Naphthalene, 3/8 lb. per gallon of oil

In spite of the fact that these trees were examined probably ten days to two weeks before the lethal effects of the treatment were

TABLE II

MOUNTAIN PINE BEETLE INFESTED LODGEPOLE PINE TREATED WITH PENETRATING SPRAYS
TREATED JUNE 10, 11 & 16, 1938 - EXAMINED JULY 10, 11 & 26, 1938

Formula A-1

Brood per Square Foot

Date examined	No of trees	On treated area intensively examined: Dead Lar.	Dead Pup.	Dead N.A.	Living Lar.	Living Pup.	Living N.A.	On treated area extensively examined: Dead	Living Lar.	Living Pup.	Living N.A.	On untreated opposite side: Dead Lar.	Dead Pup.	Dead N.A.	Living Lar.	Living Pup.	Living N.A.
7/10, 11	12*	103.0	--	.2	2.5	.7	--	75.9	1.4	.1	--	.3	.7	--	13.3	27.7	51.0
Totals		103.2			3.2			75.9	1.5			1.0			92.0		
7/26	3**	178.0	18.7	.7	--	--	--	79.5***	--	.8	.6	--	--	--	24.0	9.3	25.3
Totals		197.4			--			79.5	1.4			--			58.6		

* Treated June 10 & 11. ** Treated June 16. *** Includes data from two additional examinations on July 30.

Percent of Dead and Living

7/10, 11	12	99.8	--	.2	79.2	20.8	--	--	1.8	.1	--	33.3	66.7	--	14.5	30.1	55.4
Totals		96.3			2.6			98.1	1.9			1.1			98.9		
7/26	3	90.2	9.5	.3	--	--	--	--	--	60.0	40.0	--	--	--	40.9	15.9	43.2
Totals		100			--			98.9	1.7			--			100		

complete, the control secured was very good. It is believed that if examination of these trees could have been deferred until later, the mortality would have been found to be at least 97 percent, thus placing the results from this formula practically on a par with formulae A and A-I as to effectiveness. In table III the data are shown in condensed form.

Composition of this formula differed from formula A only in the amount of lethal material used. On the basis of results secured and the lower cost of this spray of about 25 cents per gallon, it is an improvement over either formula A or A-1.

Formula A-3

This formula contained:

Light stove oil, 3 parts
Heavy stove oil, 1 part
Orthodichlorobenzene, 1 part (by volume)
Naphthalene, 3.6 lbs. per gallon of orthodichlorobenzene

The quantity of naphthalene represents the amount that will make a saturated solution in a gallon of orthodichlorobenzene at 65° F. This is the most concentrated solution of lethal material in any of the sprays used.

Results from this formula were very good on the ten trees treated, the average mortality being over 97 percent. The data for this treatment are shown in condensed form in table IV. A comparison of this formula with the preceding three places it on at least a par with them as to control secured, but its cost of 36 cents per gallon makes it the most expensive of any tested.

TABLE III

MOUNTAIN PINE BEETLE INFESTED LODGEPOLE PINE TREATED WITH PENETRATING SPRAYS
TREATED JUNE 13-14, 1938

Formula A-2

Brood per Square Foot

Date examined	No. of trees	On treated area intensively examined						On treated area extensively examined						On untreated opposite side					
		Dead			Living			Dead	Living			Dead			Living		
		Lar.	Pup.	N.A.	Lar.	Pup.	N.A.		Lar.	Pup.	N.A.	Lar.	Pup.	N.A.	Lar.	Pup.	N.A.
7/13-14	10	58.6	13.0	1.4	.8	1.0	1.0	35.6	.6	.6	.3	1.2	--	--	7.6	1.2	34.0
Totals		73.0			2.8			35.6	2.1			1.2			42.8		

Percent of Dead and Living

7/13/14	10	80.3	17.8	1.9	28.6	35.7	35.7	--	38.1	38.1	23.8	100	--	--	17.8	2.8	79.4
Totals		96.3			3.7			95.5	4.6			2.4			97.6		

TABLE IV

MOUNTAIN PINE BEETLE INFESTED LODGEPOLE PINE TREATED WITH PENETRATING SPRAY
TREATED JUNE 22, 1938

Formula A-3

Brood per Square Foot

Date examined	No. of trees	On treated area intensively examined: Dead Lar.	Pup.	N.A.	Living Lar.	Pup.	N.A.	On treated area extensively examined: Dead Brood	Living Lar.	Pup.	N.A.	On untreated opposite side: Dead Lar.	Pup.	N.A.	Living Lar.	Pup.	N.A.
July 17-19	10	52.2	22.8	3.0	2.2	.2	.2	63.0	.7	.5	.5	--	--	.9	8.4	7.1	42.2
Totals			78.0			2.6		63.0		1.7			.9			57.7	

Percent of Dead and Living

By developmental stages for dead and living		66.9	29.2	3.8	84.6	7.7	7.7	--	43.0	29.0	28.0	--	--	100	14.6	12.3	72.3
For area examined			96.8			3.2		97.5		2.5			1.5			98.5	

Notes concerning extensive examination on treated side

Surviving brood chiefly under green or wetter portions of bark. Some surviving larvae had just hatched from recently laid eggs. Much mortality few days prior to examination and generally in mature larval and pupal stages.

Formula B

This formula contains the following ingredients:

Light stove oil, 3 parts
Heavy stove oil, 1 part
Naphthalene, 1 lb. per gallon of oil

Control secured from this formula amounted to over 95 percent in spite of the fact that many of the trees were examined in mid-July before the control effect was complete. An unusual feature of the data from these trees treated in June was the surprising uniformity in degree of control secured.

Data from the five trees sprayed early in July and examined late in the same month showed slightly less control than those treated and examined earlier in the season. Variability in material treated is believed responsible for this difference, rather than any decrease in effectiveness of the treatment. Although 50 percent of the brood had reached the new adult stage at the time of spraying of these five trees, the treatment proved effective and indicates that it is highly toxic to even that advanced stage of development of the bark beetle.

For the control secured and the cost of the ingredients, this formula at 20 cents per gallon is the best of any tested up to the present time. However, from the degree of control noted, it is felt that this formula does not cause quite as high mortality as formulae A, A-1, and A-3. Furthermore, the necessity of heating the oil to dissolve the naphthalene is an objectionable feature of this formula. This disadvantage is discussed more fully later in this report.

The data secured from trees treated with formula B are shown in table V.

TABLE V

MOUNTAIN PINE BEETLE INFESTED LODGEPOLE PINE TREATED WITH PENETRATING SPRAY
TREATED 6/21/38

Formula B

Brood per Square Foot

Date examined	No. of trees	On treated area intensively examined: Dead Lar.	Dead Pup.	Dead N.A.	Living Lar.	Living Pup.	Living N.A.	On treated area extensively examined: Dead Brood	Living Lar.	Living Pup.	Living N.A.	On untreated opposite side: Dead Lar.	Dead Pup.	Dead N.A.	Living Lar.	Living Pup.	Living N.A.
7/16-18	20	63.7	17.7	1.7	1.3	.7	1.0	57.6	1.2	.6	.8	.2	--	--	29.8	4.4	36.5
Totals				83.1			3.0				2.6			.2			70.9
7/26-28	10	34.6	12.0	11.6	1.0	.6	.2	38.7	1.5	.4	1.9	.4	--	--	7.2	7.2	60.8
Totals				58.2			1.8	38.7			3.8			.4			75.2

Percent of Dead and Living

7/16-18	20	76.6	21.3	2.1	43.3	23.3	33.3	--	46.2	23.1	30.8	100	--	--	42.0	6.2	51.8
Totals				96.5			3.5	95.7			4.3			.2			99.8
7/26-28	10	59.5	20.6	19.9	55.6	33.3	11.1	--	40.4	11.5	48.1	100	--	--	9.6	9.6	80.8
Totals				97.0			3.0	91.1			8.9			.5			99.5

Trees treated in June and examined in mid-July showed 37 percent survival for which no reason was apparent, the remaining 63 percent being apparently due to wet or green bark.

Survival in trees examined late in the season showed only 10 percent not assignable to some factor, the 90 percent being due, apparently, to wet, green, or thick bark.

Formula B-1

Ingredients of this formula were as follows:

Diesel oil, 27+
Naphthalene, 1 lb. per gallon of oil

The substitution of Diesel for the light and heavy stove oils as a carrier of the lethal material seems to have proved equally effective. Excellent results were secured, the average mortality on 23 trees being 96.5 percent. However, an unusual feature of this treatment was the high normal mortality which, if subtracted from the artificial control secured, gives a comperatively low net control creditable to the spray. This makes evaluation of the results somewhat uncertain. In other treatments normal mortality has been so low it only slightly reduced the net control and has been ignored in discussions of the results secured.

Due to the use of Diesel oil and to the comparatively cheap naphthalene flakes, this formula, at about 20 cents per gallon, has a decided advantage over others as far as cost is concerned. Again, however, we have the disadvantage of having to heat the oil to dissolve the naphthalene. If some cheap medium can be introduced in the solution that will dissolve and keep the naphthalene in solution to as low as 20° F. without the application of heat, this formula offers excellent economy and effectiveness.

The data secured are shown in table VI.

TABLE VI

MOUNTAIN PINE BEETLE INFESTED LODGEPOLE PINE TREATED WITH PENETRATING SPRAY

TREATED 6/13/38

Formula B-1

Brood per Square Foot

Date examined	No. of trees	On treated area intensively examined: Dead: Lar.	Pup.	N.A.	Totals	Living: Lar.	Pup.	N.A.	Totals	On treated area extensively examined: Dead: Brood	Totals	Living: Lar.	Pup.	N.A.	Totals	On untreated opposite side: Dead: Lar.	Pup.	N.A.	Totals	Living: Lar.	Pup.	N.A.	Totals
7/13	10	66.4	7.0	--	73.4	1.4	.8	--	2.2	41.9	41.9	1.7	.6	.2	2.5	2.4	.4	.8	3.6	5.2	4.0	34.4	43.6
7/21-23	13	75.1	4.5	1.9	81.5	1.2	.8	.8	2.8	60.1	60.1	.3	.3	1.0	1.6	1.6	.3	.3	2.2	1.9	1.2	59.1	62.2

Percent of Dead and Living

7/13	10	90.5	9.5	--	97.1	63.6	36.4	--	2.9	--	94.4	69.2	23.1	7.7	5.6	66.7	11.1	22.2	7.6	11.9	9.2	78.9	92.4
7/21-23	13	92.2	5.5	2.3	96.8	44.4	27.8	27.8	3.2	--	97.4	17.9	17.9	64.3	2.6	71.5	14.	14.3	3.4	3.0	2.0	95.1	96.6

Formula B-2

Materials used in this formula were:

Heavy oil (Diesel)
Naphthalene, 1/2 lb. per gallon of oil

Data secured from trees treated with this formula showed too high a survival on the treated areas, probably due to insufficient lethal material. Average control was found to be 86.0 percent. Cost of this formula is about 16 cents per gallon.

The data are presented in table VII.

Formula B-3

Composition of this formula is as follows:

Heavy oil (Diesel)
Naphthalene, 1/4 lb. per gallon of oil

It is quite apparent from an analysis of the data secured that the lethal material in this formula is insufficient to give adequate control, mortality amounting to but 76.9 percent of total brood. The ineffectiveness of this spray is further indicated by the presence of living brood under thin, comparatively dry bark on a number of trees. Cost of this formula was about 14 cents per gallon.

The data from these trees are presented in condensed form in table VIII.

Formula B-4

The following ingredients comprised this formula:

Light stove oil, 3 parts
Heavy stove oil, 1 part
Naphthalene, 1/2 lb. per gallon of oil

TABLE VII

MOUNTAIN PINE BEETLE INFESTED LODGEPOLE PINE TREATED WITH PENETRATING SPRAY
TREATED 6/10/38

Formula B-2

Brood Per Square Foot

Date examined	No. of trees	On treated area intensively examined: Dead Lar.	Dead Pup.	Dead N.A.	Living Lar.	Living Pup.	Living N.A.	On treated area extensively examined: Dead Brood	Living Brood	On untreated opposite side: Dead Lar.	Dead Pup.	Dead N.A.	Living Lar.	Living Pup.	Living N.A.
7/9, 10	14	81.1	5.3	1.0	13.7	2.3	.1	68.6	9.2	.6	.6	--	20.4	31.6	58.7
Totals		87.4			16.1			68.6	9.2	1.2			110.7		

Percent of Dead and Living

7/9, 10	14	92.8	6.1	1.1	81.3	7.4	5.1	--	11.9	50	50	--	18.4	28.5	53.1
Totals		83.9			16.1			88.1	11.9	.9			99.1		

TABLE VIII

MOUNTAIN PINE BEETLE INFESTED LODGEPOLE PINE TREATED WITH PENETRATING SPRAY
TREATED 6/11/38 - EXAMINED 7/11 (6), 7/22 (6), and 7/28 (1)

Formula B-3

Data per Square Foot

Date examined	No. of trees	On treated area intensively examined: Dead: Lar.	Dead: Pup.	Dead: N.A.	Living: Lar.	Living: Pup.	Living: N.A.	On treated area extensively examined: Dead: Brood	Living: Lar.	Living: Pup.	Living: N.A.	On untreated opposite side: Dead: Lar.	Dead: Pup.	Dead: N.A.	Living: Lar.	Living: Pup.	Living: N.A.
7/11, 22, 28	13	73.5	3.1	.8	14.6	4.3	3.2	51.7	9.0	4.6	3.1	1.9	.3	--	16.6	21.5	49.9
Totals		77.4			22.1			51.7	16.7								

Percent of Dead and Living

7/11, 22, 28	13	95.0	4.0	1.0	66.0	19.4	14.6	75.7	53.9	27.7	18.4	85.7	14.3	--	18.8	24.5	56.7
Totals		77.7			22.3			75.7	24.3			2.4			97.6		

This formula differs from B-2 only in the carrier for the lethal material, which is a mixture of the light and heavy stove oils rather than the Diesel oil. Surprisingly, the results obtained were quite good, indicating an average mortality of approximately 94.0 percent. Only 86.0 percent control was indicated with the formula B-2 in which the heavier Diesel oil was the carrier. With no differences other than the one given in the formula it would seem that the carrier oil was the factor responsible for the greater mortality secured. However, in the writer's opinion differences in the time of treatment and examination may be largely responsible. During the period between spraying and examination with formula B-2, June 10 to July 9, the mean maximum temperature was 68.8 and there were 24 days when more or less precipitation occurred. Only on July 9 did the temperature exceed 80° F., reaching 82° F., preceded by a previous high of 78° F. on June 22. In contrast, between the time trees were treated with formula B-4 on June 22 and examined on July 19 and 20, the mean maximum temperature was 72.5° F., on six days the temperature was 80° F. or above, and 21 days showed more or less precipitation.

It is believed that the heavier oil of formula B-2 and lower temperatures at the time of treatment so retarded penetration of the bark as to permit considerable evaporation of both the oil and lethal material, whereas with the lighter oil of formula B-4 and treatment followed by higher mean maximum temperatures, the lighter oil may have penetrated much more rapidly and carried with it a greater amount of the lethal

material. It is thought the higher temperatures would so accelerate absorption of this lighter oil by the bark as to more than offset its increase in evaporation from the bark surface. Furthermore, if control is secured more by the fumigation effect of the naphthalene than by contact, the higher temperature would probably promote its effectiveness.

The percent of control was relatively high, but the number of trees treated were too few to furnish a basis for a definite conclusion regarding its efficiency, and more experimentation is recommended.

This formula costs about 17 cents per gallon.

The data for this experiment are given in table IX.

Formula C.

Composition of this formula was as follows:

Light stove oil, 3 parts
Heavy stove oil, 1 part
Orthodichlorobenzene, 1 part (by volume)

Examination of trees treated with this formula is believed to have been done too early to show the ultimate effect of the spray. Had the data for the 20 trees examined on July 14 and 15 been secured about August 1, it is believed much greater effectiveness would have been indicated. Data from these trees showed only 89.6 percent mortality, whereas five trees treated at the same time but examined on July 26 showed an average mortality of 95.8 percent. The slower action but eventual effectiveness of this formula is further indicated by duplicate examinations of the same trees in mid and late July. From July 15 until July 30 the mortality in these trees increased from 79.8 percent to

TABLE IX

MOUNTAIN PINE BEETLE INFESTED LODGEPOLE PINE TREATED WITH PENETRATING SPRAY

TREATED 6/22/38

Formula B-4

Data per Square Foot

Date examined	No. of trees	On treated area intensively examined: Dead: Lar.	Dead: Pup.	Dead: N.A.	Living: Lar.	Living: Pup.	Living: N.A.	On treated area extensively examined: Dead: Brood	Living: Lar.	Living: Pup.	Living: N.A.	On untreated opposite side: Dead: Lar.	Dead: Pup.	Dead: N.A.	Living: Lar.	Living: Pup.	Living: N.A.
7/19, 20	10	62.6	26.0	4.0	3.0	2.4	1.8	67.7	2.1	.8	1.1	--	.4	--	4.4	4.4	61.6
Totals			92.6			7.2		67.7		4.0			.4			70.4	

Percent of Dead and Living

7/19, 20	10	67.7	26.1	4.3	41.7	33.3	25.0	100	53.3	20.0	26.7	--	100	--	6.2	6.3	87.5
Totals			92.8			7.2		94.5		5.5			.5			99.5	

TABLE X

MOUNTAIN PINE BEETLE INFESTED LODGEPOLE PINE TREATED WITH PENETRATING SPRAY
TREATED 6/17, 21, & 7/6/38

Formula C

Brood per Square Foot

Date examined	No. of trees	On treated area intensively examined: Dead Lar.	Dead Pup.	Dead N.A.	Living Lar.	Living Pup.	Living N.A.	On treated area extensively examined: Dead Brood	Living Lar.	Living Pup.	Living N.A.	On untreated opposite side: Dead Lar.	Dead Pup.	Dead N.A.	Living Lar.	Living Pup.	Living N.A.
7/14, 15	20	83.1	8.2	.5	11.9	1.3	.7	67.1	5.4	.6	.2	.2	--	--	18.6	8.2	40.6
Totals		91.8			13.9			67.1	6.2			.2			67.4		
7/26	5	62.0	32.8	1.6	.8	.8	.8	93.2	5.0	.4	.6	--	.8	--	.8	--	46.4
Totals		96.4			2.4			93.2	6.0			.8			47.2		
7/27, 28	5	21.2	16.4	22.4	.8	--	.8	44.5	.2	--	.2	2.0	--	--	--	1.0	83.0
Totals		60.0			1.6			44.5	.4			2.0			84.0		

Percent of Dead and Living

7/14, 15	20	90.5	8.9	.5	85.6	9.3	5.0	100	87.0	10.6	2.4	100	--	--	27.6	12.2	60.2
Totals		86.8			13.2			91.6	8.4			.3			99.7		
7/26	5	64.3	34.0	1.7	33.3	33.3	33.3	100	83.3	6.7	10.0	--	100	--	1.7	--	98.3
Totals		97.6			2.4			94.0	6.0						98.3		
7/27, 28	5	35.1	27.1	37.8	50	--	50	100	100	--	100	100	--	--	--	1.2	98.8
Totals		97.4			2.6			99.2	99.8			2.3			97.7		

98.5 percent. From the preceding discussion it is believed the greater effectiveness of this formula than was at first indicated is brought out.

Late Spraying With Formula C

Five trees sprayed with this formula on July 6, and examined on the 27th and 28th of the same month, revealed control amounting to 98.4 percent, which is excellent. The results further strengthen the conclusions regarding the efficiency of this formula. Cost of this formulais rather high, being about 30.5 cents per gallon.

In table X the data for trees treated with formula C are given in condensed form.

Treatment C-1

The composition of this formula was as follows:

Heavy oil (Diesel), 4 parts
Orthodichlorobenzene, 1 part (by volume)

Similar to the effect of many of the other sprays, data from this treatment indicated that early examination of the treated trees would show incomplete mortality of infesting brood, due to the delayed control characteristic of these formulae. It is felt that the data for the various dates of examination show this quite clearly in table XI.

TABLE XI
MORTALITY CHANGES IN LODGEPOLE PINE INFESTED BY THE MOUNTAIN PINE BEETLE AND TREATED WITH FORMULA C-1

No. of trees examined	Date examined	Percent of mortality	Type of examination
3	6/25/38	68.0	Extensive and intensive
Same 3 as above	7/8/38	91.7	" only
10	7/8/38	82.5	" and intensive
12	7/30/38	95.3	" only

The increase in the percent of mortality as the lapse of time between treatment on June 9 and examination is increased, is readily seen. Just as with the other oils, the larvae are not immediately killed by the treatment but remain alive, although inactive, for a more or less extended period before dying.

The success obtained with this formula is about equal to that in which both light and heavy stove oils were used. The Diesel oil may then be considered the better of the two carriers, as it is cheaper and does not involve the necessity of measuring and mixing the two oils.

Cost of this formula at present prices of materials is about 30 cents per gallon. The data for the trees sprayed with this formula are condensed in table XII.

Formula C-2

This formula varies from C-1 only in the amount of lethal material, as follows:

Heavy oil (Diesel), 4 parts
Orthodichlorobenzene, 1/2 part (by volume)

TABLE XII

MOUNTAIN PINE BEETLE INFESTED LODGEPOLE PINE TREATED WITH PENETRATING SPRAY
TREATED 6/9/38

Formula C-1

Brood per Square Foot

Date examined	No. of trees	On treated area intensively examined: Dead Lar.	Dead Pup.	Dead N.A.	Dead Totals	Living Lar.	Living Pup.	Living N.A.	Living Totals	On treated area extensively examined: Dead Brood	Living Lar.	Living Pup.	Living N. A.	Living Totals	On untreated opposite side: Dead Lar.	Dead Pup.	Dead N.A.	Dead Totals	Living Lar.	Living Pup.	Living N.A.	Living Totals
6/28	3	40.7	--	--		19.3	--	--		14.3	6.7	--	--		2.0	--	--		70.7	21.3	1.3	
Totals					40.7				19.3	14.3				6.7				2.0				93.3
7/8, 10	10*	100.8	1.8	--		22.8	.8	--		70.6	12.0	--	--		1.2	.8	.2		30.8	39.0	24.0	
Totals					102.6				23.6	70.6				12.0				2.2				93.8
7/30	12**									112.3	.4	1.4	.1									
Totals										112.3				1.9								

Percent of Dead and Living

6/28	3	100	--	--		100	--	--		--	100	--	--		100	--	--		75.7	22.8	1.4	
Totals					67.8				32.2	68.3				31.7				2.1				97.9
7/8, 10	10*	98.2	1.8	--		96.6	3.4	--		--	100	--	--		54.6	36.3	9.1		32.8	41.6	25.6	
Totals					81.3				18.7	85.5				14.5				2.3				97.7
7/30	12**									--	21.4	71.4	7.1									
Totals										98.3				1.7								

* Includes all 13 trees on the extensive examination.

** Includes 12 trees extensively examined.

In spite of the fact that examination of ten trees on July 18 revealed incomplete control, the mortality indicated was 91.9 percent, which is very good. The four trees which showed the greatest survival at that time were reexamined on July 30. The indicated mortality during that period rose from 86.4 to 97.8 percent.

Considering that the control secured with this formula was practically as good as with double the quantity of orthodichlorobenzene used in formula C-1, this mixture should be given further trial because of the greater economy offered. At present prices this mixture would cost about 22.5 cents per gallon.

It is believed that comparatively early examinations are responsible for most of the wide variation in percent of control found in the treated portion of these trees, but an additional high normal mortality leaves the results of this test in a somewhat doubtful status. In spite of these unfavorable indications it is believed further tests will show that this formula is highly effective.

A condensation of the data for formula C-2 is shown in table XIII.

Formula M

This formula comprised oil and lethal agent in the following proportions:

Heavy oil (Diesel), 4 parts
Ethylene dichloride, 1 part (by volume)

TABLE XIII

MOUNTAIN PINE BEETLE INFESTED LODGEPOLE PINE TREATED WITH PENETRATING SPRAY
TREATED 6/20/38

Formula C-2

Brood Per Square Foot

Date examined	No. of trees	On treated area intensively examined: Dead Lar.	Dead Pup.	Dead N.A.	Living Lar.	Living Pup.	Living N.A.	On treated area extensively examined: Dead Brood	Living Lar.	Living Pup.	Living N.A.	On untreated opposite side: Dead Lar.	Dead Pup.	Dead N.A.	Living Lar.	Living pup.	Living N.A.
7/18/38	10	69.0	21.2	3.4	4.6	1.2	2.2	40.1	2.3	.2	1.1	1.2	--	4.8	22.8	5.2	28.4
Totals			93.6				8.0	40.1			3.6			6.0			56.4
7/30/38	4							126.8	1.1	--	2.9						
Totals								126.8			4.0						

Percent of Dead and Living

7/18/38	10	73.7	22.6	3.6	57.5	15.0	27.5	--	64.6	6.2	29.2	20.0	--	80.0	40.4	9.2	50.3
Totals			92.1				7.9	91.7			8.3			9.4			90.6
7/30/38	4							--	28.6	--	7.4						
Totals								97.8			2.2						

Study of the data indicates a decided arresting of development of the brood surviving. Had time permitted another examination of these trees about August 1, it is probable that a much higher mortality would have been revealed. The considerable survival just discussed, and a high normal mortality, place this formula in a doubtful status as to its efficiency, indicating the need for further tests. However, if we consider the sickly larvae as part of the control secured, mortality was at least 93 percent, which is good.

This formula at 23 cents per gallon is quite reasonable in cost.

The data secured are shown in table XIV.

Formula M-1

The material used in this formula was as follows:

Heavy oil (Diesel), 2 parts
Ethylene dichloride, 1 part (by volume)

Exceptionally fine results were obtained with this spray. Only two of the ten trees treated revealed any survival under the intensively examined samples. Seven of the same ten trees showed light survival under 12 square feet of bark extensively examined. The average mortality for extensive and intensive examinations was 96.8 percent, but much of the survival was in the larval stage and many of them were sickly. If the latter may be considered as part of the control, approximately 99 percent control was secured with this formula.

Cost is the factor which may eliminate this formula from further consideration, as it amounts to about 30 cents per gallon on the basis

TABLE XIV

MOUNTAIN PINE BEETLE INFESTED LODGEPOLE PINE TREATED WITH PENETRATING SPRAY

TREATED 6/23/38

Formula M

Brood per Square Foot

Date examined	No. of trees	On treated area intensively examined: Dead Lar.	Dead Pup.	Dead N.A.	Living Lar.	Living Pup.	Living N.A.	On treated area extensively examined: Dead Brood	Living Lar.	Living Pup.	Living N.A.	On untreated opposite side: Dead Lar.	Dead Pup.	Dead N.A.	Living Lar.	Living Pup.	Living N.A.
7/19, 20	10	34.8	10.4	.6	6.4	.2	--	32.8	2.8	.3	.2	1.2	--	.8	2.0	--	12.0
Totals			45.8			6.6		32.8		3.3			2.0			14.0	

Percent of Dead and Living

7/19, 20	10	76.0	22.7	1.3	97.0	3.0	--	--	84.1	9.1	6.8	60.0	--	40.0	14.3	--	85.7
Totals			87.4			12.6		90.8		9.2			12.5			87.5	

of prices in 1938. However, after comparing the data for formulae M and M-1, it is believed acceptable results could be secured by reducing the amount of lethal agent to one part in four of the total volume instead of one in three used in this formula. This would reduce the cost per gallon to about 26.5 cents. It is also possible that the proportions used in formula M will be found to give good control with further experimentation, which would place that solution in a very favorable position for consideration as a control medium.

The data for this treatment are shown in table XV.

Formulae D-1-a, b, c, d, e

The ingredients in these formulae were as follows:

Water
Ammonium thiocyanate, 1 lb. per gallon of water
Wetting agents, 1 percent by weight, as follows:

Santamerse D	D-1-a
Arctic syntex M (powder)	D-1-b
Vatsol OT	D-1-c
Arctic syntex M (flakes)	D-1-d
Arctic syntex A (powder)	D-1-e

It is realized that any alteration of the properties of water that would induce ready penetration of the bark would make available a cheap and readily obtainable carrier for the lethal agent used. With the idea of making such a change, wetting agents which serve to reduce the surface tension of water were added to a solution of a lethal material in water. Five trees were treated with each of five formulae which varied only in the wetting agent.

TABLE XV

MOUNTAIN PINE BEETLE INFESTED LODGEPOLE PINE TREATED WITH PENETRATING SPRAY
TREATED 6/23/38 - EXAMINED 7/20-21/38

Formula M-1

Brood per Square Foot

Date examined	No. of trees	On treated area intensively examined: Dead: Lar.	Pup.	N.A.	Total	Living: Lar.	Pup.	N.A.	Total	On treated area extensively examined: Dead: Brood	Total	Living: Lar.	Pup.	N.A.	Total	On untreated opposite side: Dead: Lar.	Pup.	N.A.	Total	Living: Lar.	Pup.	N.A.	Total
7/20, 21	10	42.4	37.4	6.4		.2	.4	.2		51.8		2.3	.2	.1		--	1.2	2.0		23.2	2.8	58.8	
Totals					86.2				.8	51.8					2.6				3.2				84.8

Percent of Dead and Living

7/20, 21	10	49.2	43.4	7.4		25.0	50.0	25		--		90.3	6.5	3.2		--	37.5	62.5		27.4	3.3	69.3	
Totals					99.1				.9	95.2					4.8				3.6				96.4

When these trees were examined there was no indication of control. Apparently the changes in the properties of water had been insufficient to make it penetrate the bark and reach the infesting brood beneath.

Although no control was secured with these sprays it was thought the spreaders, if they would break the surface tension of oils, might increase the effectiveness of the sprays by inducing more ready penetration of the bark. If that occurred it seemed possible the amount of lethal material, which is the item of high cost, might be reduced. Accordingly, in September 1938 the following formulae were tested on trees attacked that year.

Formula A and Vatsol OT
7 trees

Formula C and Vatsol OT
6 trees

In addition to the preceding tests, the effects that the surface tension reducers might have on the lethal qualities of the oil were tested by treating five trees with the oil itself and five additional trees with the same oil plus Vatsol OT.

Wishing to make further tests of the possibilities of fall control, three formulae which gave excellent results when used in the spring of the year were sprayed on fifteen trees in the following order.

Formula C
5 trees

Formula A
5 trees

Formula A-1
5 trees

Data from the preceding seven treatments will not be available until late July of 1939, at which time it is planned to make the final examination of them.

DISCUSSION OF RESULTS

If the ultimate control effects of penetrating sprays could be obtained shortly after treating, accurate control data would be available after the lapse of a few days following it. However, with many of the formulae it was found that even six weeks after spraying, a few of the many larvae whose development had been arrested by the treatment were still alive. Under such conditions only the data secured near the end of this period gives a satisfactory measure of treatment effectiveness. However, the large number of trees to be examined prohibits securing the necessary data in less than from two to three weeks. Therefore, the trees examined first show a much larger proportion of incomplete control than those examined later. In order to compare formulae on an equal basis a correction factor was developed. Fortunately, duplicate examinations of some of the trees treated with the same spray were made on different dates, thereby yielding data which gave an excellent index of rate of mortality between examinations. In addition, hardly a day passed without the completion of examination data of one or more treatments. These, and the preceding data, provided an almost unbroken series from which daily brood mortality could be determined. The completed data showed a decided trend toward higher mortality with the passage of

each day. It was found that by adding to the percent of control of any formula a figure equal to one-half the number of days from the time examined until July 31, a total was obtained that averaged slightly less than 100 for the data as a whole, exclusive of that for treatments B-3 and M and for the initial examination data of treatment C-1. This combined figure might well be considered as approximating the percent of final control secured. July 31 was set as the final date because it was necessary to terminate all examinations the preceding day. Mortality of the small remainder of living brood on treated areas on July 31 was still occurring, although decreasing, and probably affecting final mortality data very little. A second reason for terminating examinations on that date was that emergence of brood from untreated areas was rapidly increasing and had reached about 20 percent of the total brood on that date. Subsequent examinations of untreated portions would have yielded data of uncertain value to compare with that from treated areas. Practically no emergence had occurred from surviving brood on treated areas.

To show more clearly the trend of the mortality, table XVI is presented. (Page 38)

From inspection of this table it will be noted that the addition of the correction factor to the secured percent of control gives a total in excess of 100 in some cases. Such totals may be considered as an indication of more rapid initial action and greater effectiveness than the average formula induced. In addition to the data given,

TABLE XVI

CORRECTION FACTOR AND COST DATA FOR PLACING VARIOUS SPRAYS ON A COMPARATIVE BASIS

Treatment	No. of trees examined	Date examined	No. days from examination to July 31	Percent of control	% control + ½ no. of days from exam. to 7/31	Relative standing based on preceding figure	Cost per gal. of formula	Relative standing based on ½ cost	Final standing, ½ of total of A and B
C-1	3	6/28	33	67	83.5	18	$.28	8	13
C-1	10	7/8 & 7/10	22	83	94	15	.28	8	11.5
B-2	14	7/9, 10	21.5	86	97	13	.16	2	7.5*
A-1	12	7/10, 11	20.5	96.5	107	1	.32	11	6
A	20	7/11 to 13	19	96	105	2	.34½	12	7
B-1	10	7/13	18	91.5	100.5	7	.20	4	5.5*
A-2	10	7/13, 14	17.5	94.5	103.5	3	.25	7	5
C	20	7/14, 15	16.5	89.5	98	11	.30½	10	10.5
B-3	13**	7/11, 22, 28	Aver. 14	75.5	82.5	19	.14	1	10*
B	20	7/16 to 18	14	96	103	4	.20	4	4*
C-2	10	7/18	13	87	93.5	16	.22	5	10.5
A-3	10	7/17 to 19	13	96.5	103	4	.36	13	8.5
M	10	7/19 to 20	11.5	83	89	17	.23	6	11.5
B-4	10	7/19 to 20	11.5	93.5	99	10	.17	3	6.5*
M-1	10	7/20 to 21	10.5	95	100.5	7	.30	9	8
B-1	13	7/21 to 23	9	95.5	100	8	.20	4	6*
A	5	7/25	6	98.5	101.5	6	.34½	12	9
C	5	7/26	5	95.0	97.5	12	.30½	10	11
A-1	3	7/26	5	99.5	102	5	.32	11	8
B	10	7/26 to 28	4	93	95	14	.20	4	9*
A	5	7/27 to 28	3.5	100	102	5	.34½	12	8.5
C	5	7/27 to 28	3.5	97	98.5	10	.30½	10	10.0
C-1	12	7/30	1	98.5	99	9	.28	8	8.5
C-2	4	7/30	1	98	98.5	10	.22	5	7.5

* Eliminated from consideration due to necessity of applying heat to dissolve naphthalene in oil.

** Sixteen trees treated 7/11, six on 7/22 and one on 7/28.

the relative effectiveness of each formula has been shown in the table by considering the highest total as indicating the greatest effectiveness and rating it as 1 with the next highest as 2 and so on to the lowest number. A second rating is based on the cost per gallon of the spray, the cheapest being rated 1 and the more expensive higher. Where two or more formulae show the same total or cost they are given the same rating. An average rating is then secured by adding those for control and cost and dividing by two. Formulae of the oil-naphthalene series (B, B-1, B-2, B-3, and B-4) received the best rating as a group but are not considered superior because of the necessity of heating the oil to 90° Fahrenheit or higher in order to dissolve the naphthalene crystals. This extra step is not only inconvenient and a source of danger at times but would probably increase the price per gallon to the point where these formulae would cost only slightly less and possibly even more than the others. Eliminating this series from present consideration we find that next in relative value is the oil-naphthalene-orthodichlorobenzene series (A, A-1, A-2, and A-3). They gave the best control of any of the groups but their cost is high. However, in formula A-2, we find comparatively low cost combined with excellent, although not the best, control. Evaluated on the basis of both cost and effectiveness we consider it superior to even the oil-naphthalene series. In addition there is the background of a long series of successful control experiments with formulae containing these ingredients. Based on control effectiveness and low cost, we consider formula A-2 as the best spray so far developed.

Formulae of the oil-orthodichlorobenzene composition gave control only slightly less effective than the oil-naphthalene series. The high cost of the orthodichlorobenzene, when in sufficient concentration to be sure of a high percent of kill, makes these formulae less acceptable than those of lower cost.

The mixture of two parts carrier oil to one ofethylene dichloride, tried for the first time during the 1936 season, gave excellent results but experience with it is limited to ten trees and the data from one of them falls outside the allowable limit of statistical error. Therefore, until more data are secured no definite recommendations are being made but further tests are proposed at the earliest opportunity.

Apparently Diesel oil as the carrier of the lethal material is equal to light and heavy stove oil. The lower cost of the Diesel fuel and elimination of the necessity of mixing two different oils make it superior.

With a number of formulae giving acceptable control the recommendation of any particular one must be based on present prices and experience. Therefore any change in the price of the lethal materials used may place some other formula at the head of the recommended list. Furthermore, if some inexpensive material can be added to the oil-naphthalene spray that would obviate the necessity of heating to dissolve the naphthalene, the formula containing the latter material might well replace the one now recommended.

Failure to recommend some treatments, even though excessive variation was not found in the data secured, is due to the wide variation noted in number of brood per unit area in lodgepole pine. These variations have been noted on the same tree, between trees in the same groups, between groups, and between localities. Because of these conditions it is felt that the experience of at least two years of trial of at least the type of treatment or of a large series of trees treated with the spray in question should be secured before recommending any formula.

Recommendations for Further Tests

During the coming season it is planned to continue the search for cheaper and more effective formulae as well as to improve technic of application of the sprays. Use of "wetting agents" which reduce the surface tension of liquids are to be given as exhaustive tests as conditions permit.

In addition to the preceding plans it is also hoped that tests of sprays on mountain-pine-beetle-infested whitebark pine can be initiated during the coming season.

SUMMARY

During the field season of 1938 tests were made of penetrating sprays on mountain-pine-beetle-infested lodgepole pine. Excellent

results were secured with a number of formulae, using a mixture of orthodichlorobenzene and naphthalene in a "carrier" of Diesel, or a combination of light and heavy stove oils. However, the high cost of these formulae as compared with the cheaper and only slightly less effective ones containing only orthodichlorobenzene or naphthalene, leaves little to choose between them. Considering both effectiveness and cost, formula A-2, containing light and heavy stove oils as the "carrier" and reduced amounts of naphthalene flakes and orthodichlorobenzene as the lethal agents, gave the best results. Although this formula was rated the highest it is believed the use of Diesel oil as the carrier in place of the light and heavy stove oils would have given equally good results.

The general effect of many of these solutions was to arrest development of the brood, a condition which persisted over a more or less lengthy period, until death of the insect. This effect was most noticeable in the larval stage.

Spraying trees within from 9 to 10 days of the time when emergence could be expected still resulted in excellent control.

A mixture of carrier oil with ethylene dichloride gave indication of being a very effective spray.

Efforts to make effective sprays of aqueous solutions of poisons by the addition of a "wetting agent" to increase penetrability were unsuccessful.